



Small Wind Systems for Rural Energy Supply

Small Wind Systems Tutorial
Village Power Conference Workshop



2 Billion People in the Dark

The Rural Electrification Problem

- ◆ ~ 2 Billion People in the World without Electric Service **(And Growing!)**
- ◆ Full Electrification with Grid-Extension is Not Economically Feasible
- ◆ Diesel Stations Work Poorly for Low Loads and are Very Sensitive to Quality of Maintenance



Village Power: A Time For Change

- ◆ **Renewable energy and electronics technologies have matured significantly over the last two decades**
- ◆ **Decentralized systems are starting to make an impact**
 - ◆ **China:** 150,000 small wind turbines installed
 - ◆ **Mexico:** 50,000 PV home systems
 - ◆ **Nepal:** 700 micro-hydro systems installed
- ◆ **Decentralized systems offer the prospect of lowering "cost of service" closer to "ability to pay", improving the economic viability (ie, lower subsidies required)**
- ◆ **Numerous renewable energy system configurations available to match resources, applications, and level of service requirements**



Modern Small Wind Turbines

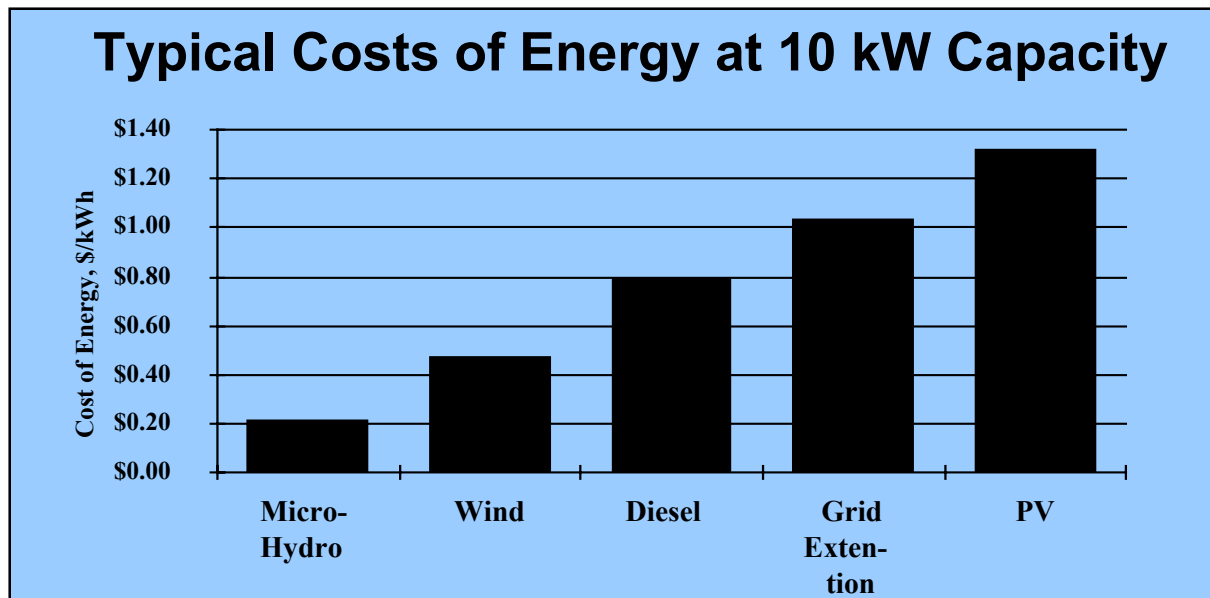
High Tech, High Reliability, Low Maintenance

- ❖ **Products from 400 W – 50 kW**
- ❖ **Technically Sophisticated**
- ❖ **Only 2-3 Moving Parts**
- ❖ **Passive Controls**
- ❖ **Rugged and Reliable**
- ❖ **Very Low Maintenance Requirements**

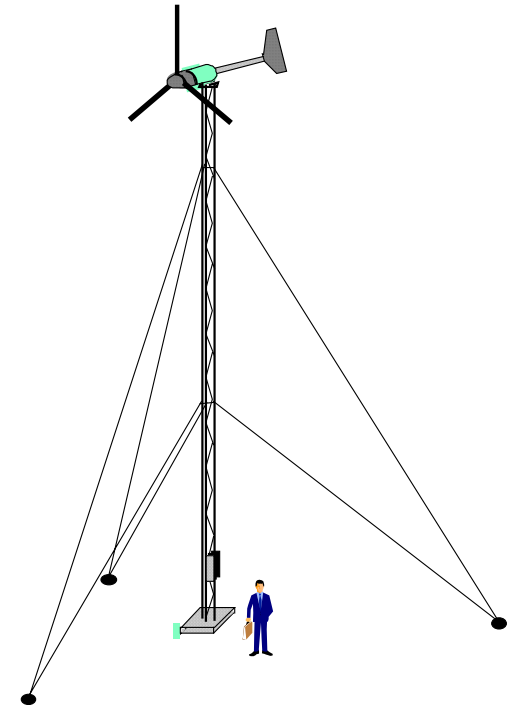


(Not to scale)

Modern Small Wind Turbines: A Least-Cost Option for Small Power



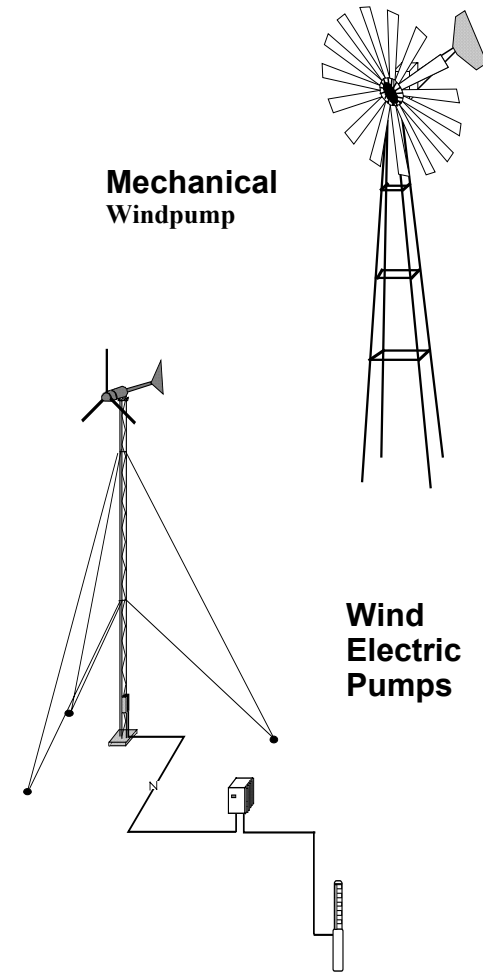
" With reasonable assumptions concerning discount rates, capacity factors, and fuel costs, micro-hydro and wind turbines can have the lowest life cycle costs in locations where the resource is sufficient."



*Fueling Development: Energy Technologies for
Developing Countries, April, 1992
U.S. Office of Technology Assessment*

Village Power: Potable Water

- ◆ Drinking water for people and livestock
- ◆ Using underground water solves common health problems
- ◆ Creating a village water tap eliminates need to carry water from distant sources
- ◆ Energy requirement is proportional to population served and pumping height
- ◆ Typical size: 1 kW : 200 people
- ◆ Water storage: 3 - 7 days



Water for People and Livestock

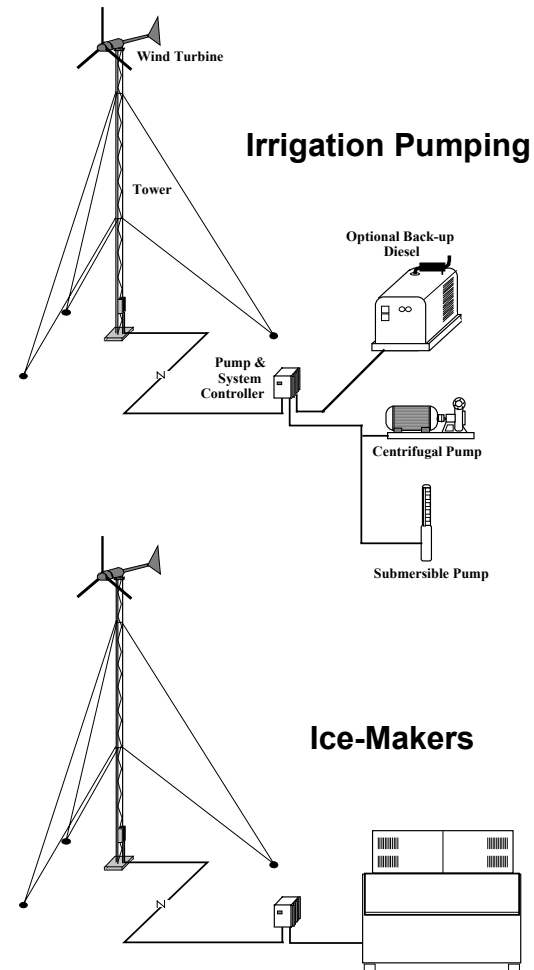
Community Water Supply: Niama, Morocco

- ◆ **Equipment:** Two Sites: (2)10 kW Wind Turbines; 18 & 24 m Towers; 15 & 26 Stage Submersible Pumps
- ◆ **Performance:** 70 m³ & 30m³ of Water per Day
- ◆ **Cost:** ~\$100,000, Including Tech. Assist. and Training, US-AID Funded
- ◆ **Installation:** February, 1990
- ◆ **Results:** Supplies 4,000 People with 220% More Water Than Original Diesel Pumps. Population Decline has been Reversed.



Village Power: Productive Uses

- ◆ Uses of energy that specifically increase income: irrigation, agro-processing, ice-making, etc.
- ◆ Excellent foundation for electrification: increases income and chances for cost recovery
- ◆ Economic incentive for sustainability
- ◆ Requires more energy than drinking water or pre-electrification, so small wind systems are an attractive technology choice
- ◆ Typical size: 1 kW : 10 people



Productive Uses

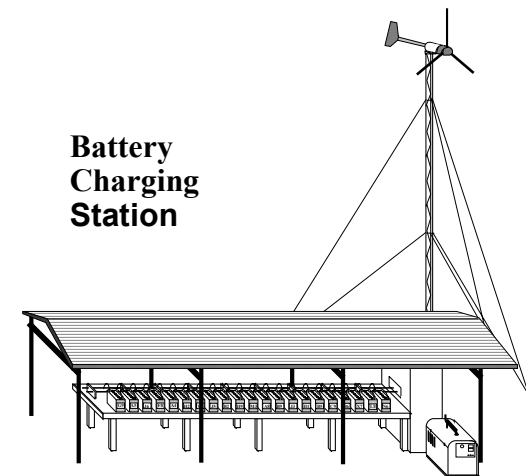
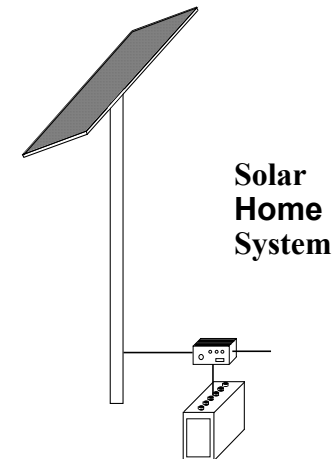
Small Plot Irrigation: Oesao, Timor, Indonesia

- ◆ **Equipment:** 1.5 kW Wind Turbine with 18m Tower; 10 Stage Pump
- ◆ **Performance:** ~ 150 m³ of Water per Day
- ◆ **Cost:** ~\$11,000
- ◆ **Installation:** July, 1992
- ◆ **Results:** ~ 25 Additional Systems Installed, JICA & US-AID Funding



Village Power: Pre-Electrification

- ◆ Provides lighting and entertainment: services that are highly valued
- ◆ Replaces existing household expenditures for kerosene, candles, and dry-cell batteries
- ◆ All direct current (DC), no grid
- ◆ Lighting done with high efficiency florescent bulbs
- ◆ Very small installed capacity: 25 - 120 Watts / household
- ◆ Solar home systems are becoming common
- ◆ Wind home systems and wind battery charging stations are emerging



Entry-Level Electrification

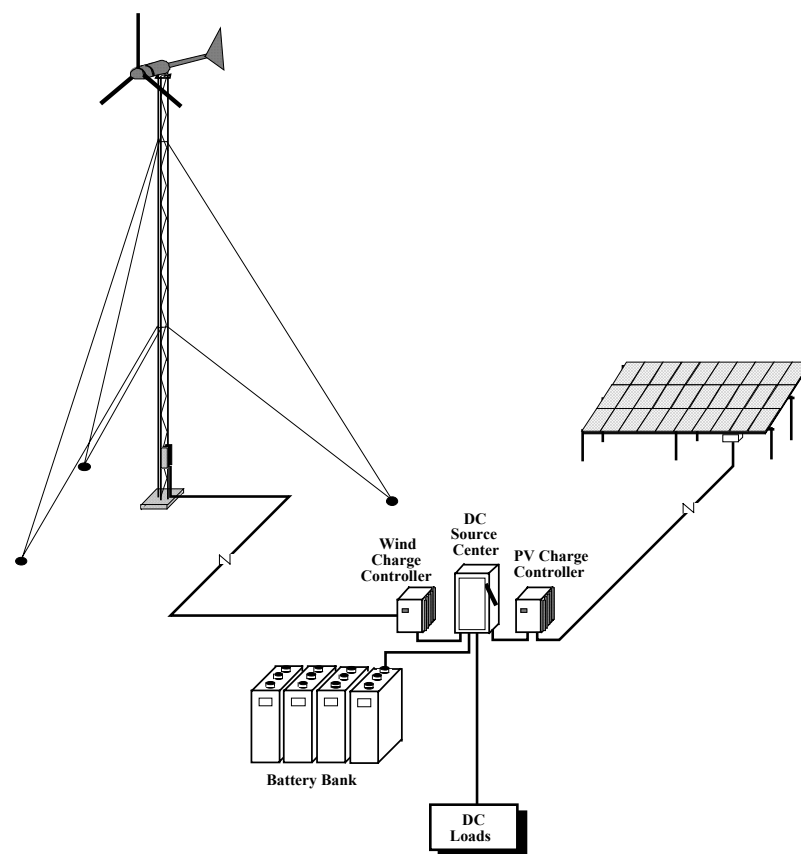
Battery Charging Station: Tomenas, Timor, Indonesia

- ◆ **Equipment:** 7.5 kW BWC Wind Turbine with 30m Tower
- ◆ **Performance:** Charges batteries for ~40 homes, plus powers productive uses (freezers, shop tools)
- ◆ **Cost:** ~\$60,000
- ◆ **Installation:** 1997
- ◆ **Results:** Sustainable electrification which costs each family ~\$2.40 per month. One of ~15 similar projects under WIND project
- ◆ **Contact:** Peter Williams, Winrock Int'l, Tel: 703-525-9430



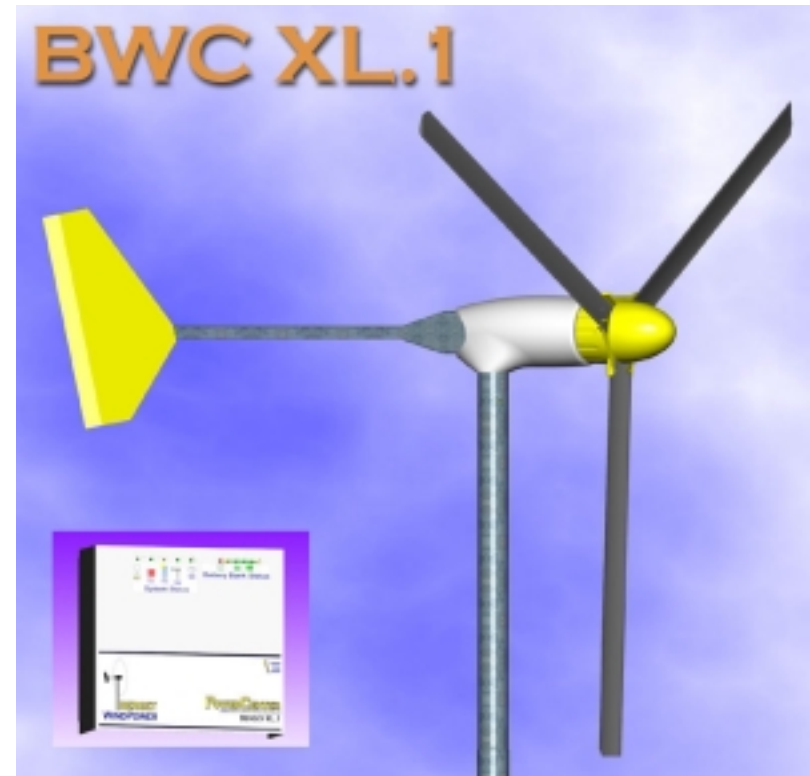
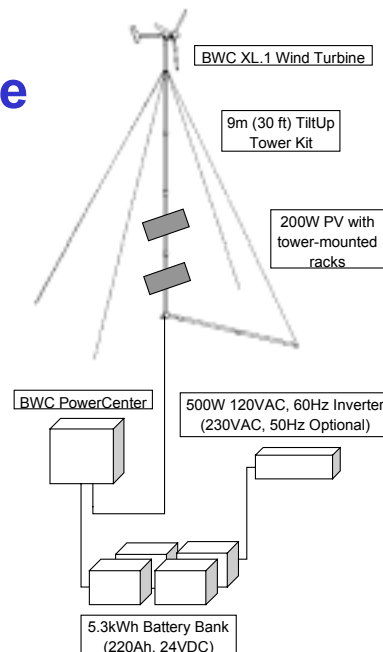
Village Power: Small Hybrids

- ◆ Provide facility power (school, clinic, etc.) or multiple home electrification
- ◆ AC output from inverter
- ◆ Wind & solar resources complement each other seasonally
- ◆ Often there is no back-up generator
- ◆ Sometimes replaces or supplements “portable” generators
- ◆ Typical Size: 1.5 kW, for school



1.2 kW Wind/Solar Hybrid System

- ❖ Based on advanced technology small wind turbine
- ❖ Install: 2 people, 3 hours, no concrete or special tools
- ❖ 3 - 7 AC kWh per day
- ❖ UPS shippable
- ❖ ~ \$4,000 for complete system (~ \$2,800 w/o Solar)

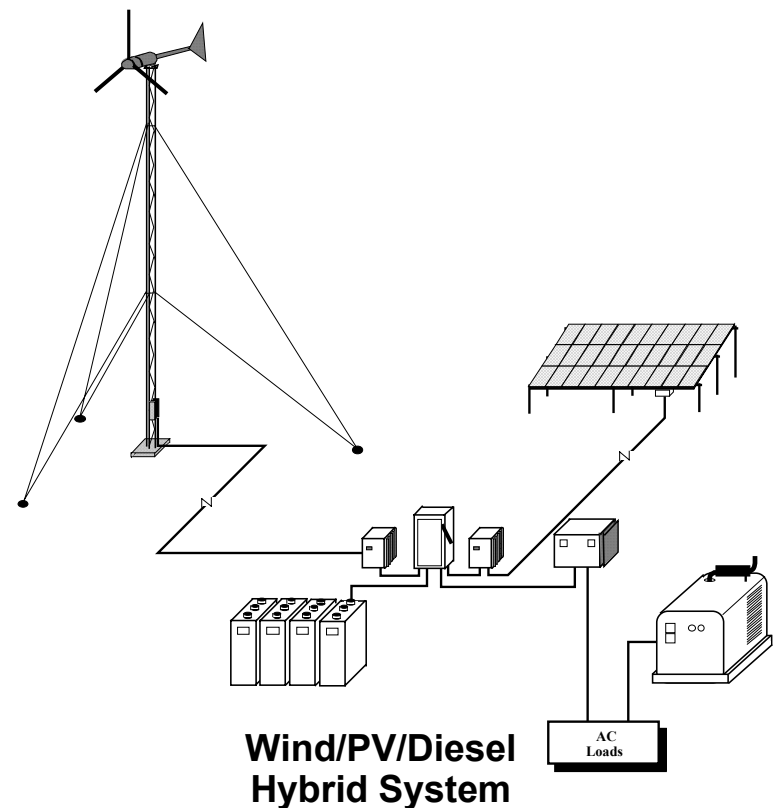


**1 kW Wind
0.2 kW Solar
30' Tilt Tower
5.3 kWh Battery
0.5 kW Inverter**



Village Power: Mini-Grid Electrification

- ◆ Provides “grid quality” AC power
- ◆ Reliable power delivery due to battery storage and back-up generation
- ◆ Allows use of standard AC appliances, including refrigerators
- ◆ Modular architecture allows multiple turbines and other generating sources, such as solar
- ◆ Typical size: 10 kW : 20 homes
- ◆ Provides 24 hour per day power with diesel run time reduced to as little as 10%
- ◆ Renewables typically supply 60 - 85% of the energy



Chile Regional Electrification

Wind/Diesel Favored Over Diesel-Only

- ◆ Collaboration Between CNE, Regional Governments, NREL, and NRECA
- ◆ 1997: Region IX Pilot Projects
- ◆ 2000: Region X Pilot Projects
- ◆ 2000-2002: Regional Implementation:
Isla de Chiloe
~ Thirty 3-40 kW
Wind/Diesel
Systems



1997

2000



Mexico Village Electrification

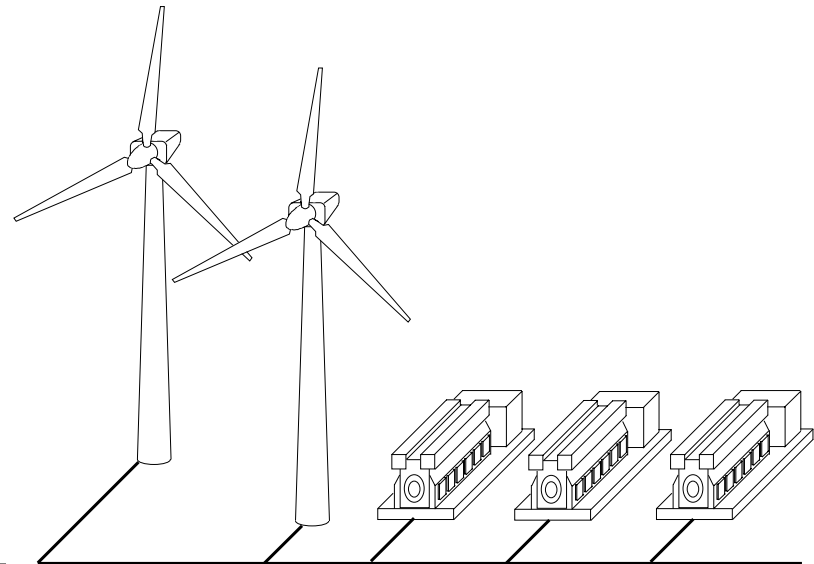
San Juanico, Baja California Sur

- ◆ **Equipment:** (10) BWC 7.5 kW Wind Turbines with 37 m Towers; 17 kW PV; 420 kWh Battery, 70 kW Inverter
- ◆ **Performance:** ~ 500 kWh / Day; Winds Average ~ 5 m/s
- ◆ **Cost:** ~ \$1,000,000
- ◆ **Installation:** March, 1999
- ◆ **Results:** USIJI Joint Implementation Project. Participants are CFE, BCS State, Arizona Public Service, US-DOE, & US-AID/Mexico. Analyses by NREL
- ◆ **Contact:** Dr. Peter Johnston, APS, Tel: 602-250-3020



Village Power: Fuel-Saver System

- ◆ AC-Bus architecture
- ◆ Retrofits to existing diesel mini-grid systems
- ◆ Mostly use AC type, induction generator wind turbines of larger sizes
- ◆ Sophisticated controls and dump loads allow high wind penetration
- ◆ Typical Size: 50 kW – 500 kW



Wind/Diesel System

Saving Diesel Fuel

Kotzebue, Alaska

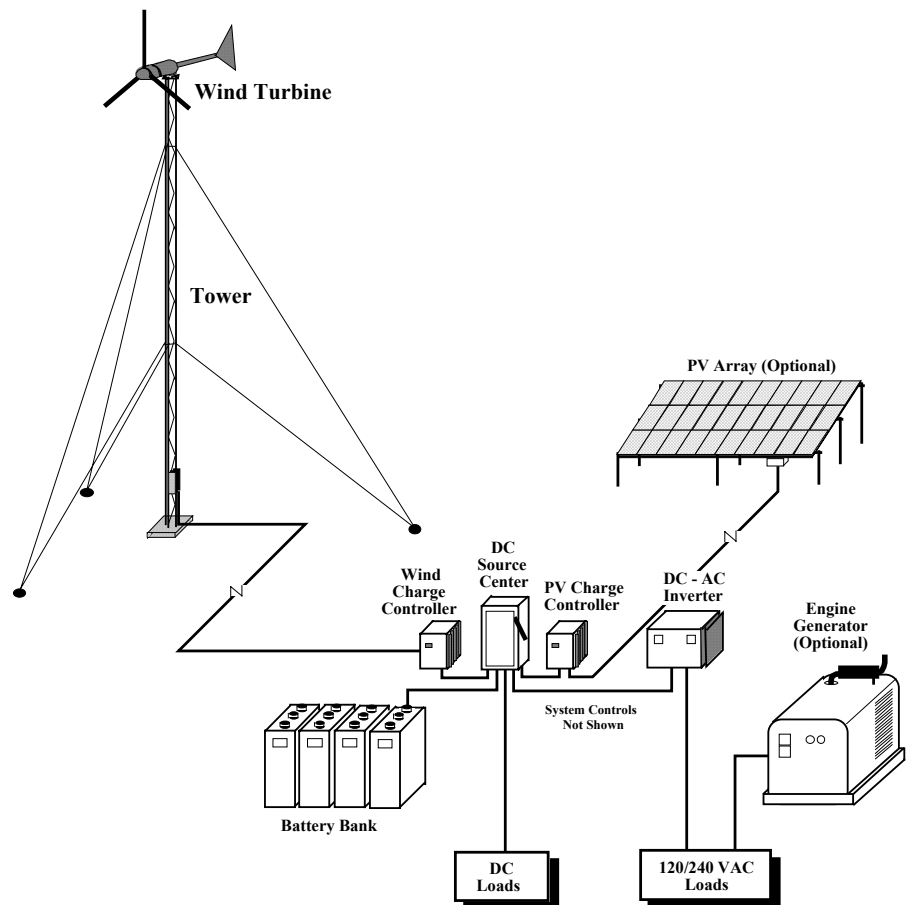
- ◆ **Equipment:** (10) AOC 50 kW Wind Turbines with 24 m Towers
- ◆ **Performance:** ~ 3,200 kWh / Day;
Winds Average ~ 5.4 m/s
- ◆ **Cost:** ~ \$1,600,000 (High installation costs due to harsh conditions)
- ◆ **Installation:** 1997 (3) & 2000 (7)
- ◆ **Results:** Wind produces 1200 MWh / Year, ~ 6% of Village Load. System being expanded.
- ◆ **Contact:** Brad Reeve, Kotzebue Electric, Tel: 907-442-3491



Hybrid Systems

The New Way to Electrify Villages

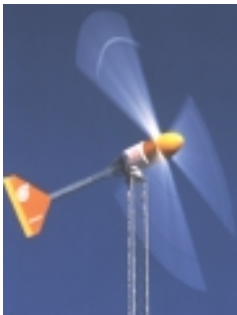
- ◆ Lower costs than grid extension in many cases
- ◆ Autonomous system power often more reliable than grid power
- ◆ Much higher service level than “6 hours of diesel each night”
- ◆ Very modular
- ◆ Standardized packages
- ◆ Battery watering is the major operational burden
- ◆ Full automation relatively easy



Hybrid Systems

Wind Turbines and Diesels are Complimentary:

<u>Characteristic</u>	<u>Wind</u>	<u>Diesel</u>
Capital Cost	High	Low
Operating Cost	Low	High
Logistics Burden	Low	High
Maintenance Req'mts	Low	High
Available On-Demand	No	Yes

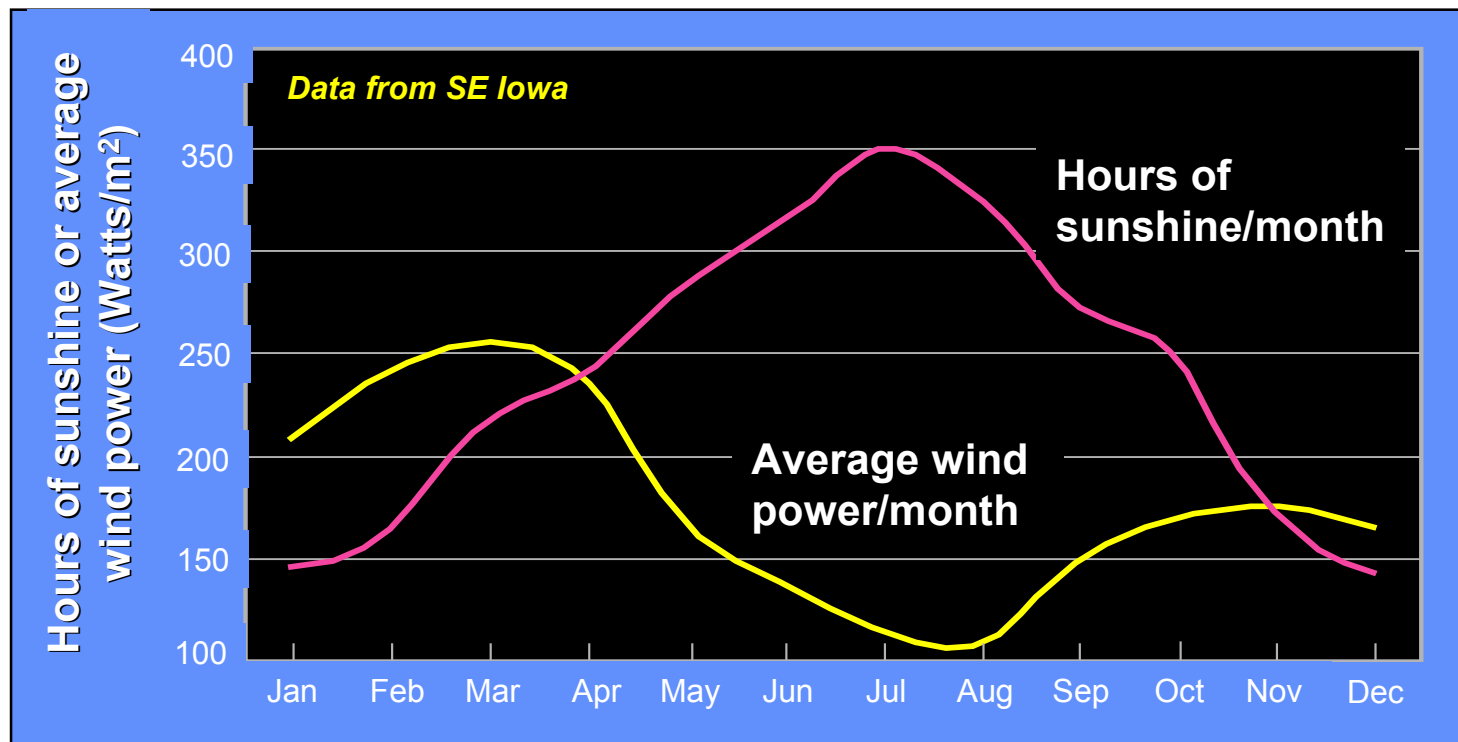


**Together, They Provide a
More Reliable and Cost-
Effective Power System
Than is Possible With
Either Wind or Diesel
Alone**



Hybrid Systems

- ◆ Wind and Solar Often have Seasonally Complimentary Resources



Hybrid Systems

- ◆ ~ 75% of the World has sufficient wind for small wind turbines
- ◆ ~ 100% of the World has either sufficient wind or sufficient solar, or both

**Wind and Solar Hybrids can
Provide Effective Power
Generation for Small Systems
Virtually Everywhere !**



China Rural Electrification

World's Largest Market for Small Wind

- ◆ 150,000 Existing Systems
- ◆ Wind/PV Hybrid Home Systems
... SETC / World Bank Project:
30,000 New Hybrid Systems
- ◆ SDPC “Brightness Engineering” Village Power Program ... ~ 35,000 5-10 kW Wind/Diesel Systems
- ◆ Foreign Cooperation to Improve Technology ... Hua De (donor-aid) & Xiangtan Bergey Windpower Ltd (private sector JV)



Small Wind is a Powerful “Weapon” in the War on Poverty

- ◆ **PV – Solar Home Systems are Not a Silver Bullet for Rural Electrification ... Consumers Often Want More Than ~ 200 Wh/Day, Direct Current**
- ◆ **For Low Load Applications (< 10 kWh/day), Wind/PV Hybrid Systems are Very Attractive**
- ◆ **For Larger Applications, Wind/Diesel Hybrids are Very Attractive**
- ◆ **Bilateral and Multilateral Finance and Market Stimulation Programs Should be Best Service at Least Cost ... Currently Too Much Technology Bias towards Solar**

